

Menu Planning of Bento Meals Based on Mathematical Optimization Considering the Similarity of Dishes and Ingredients

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Abstract

"Bento" is widely known as a part of Japanese food culture. There are many companies in Japan that manufacture thousands of bento every day and deliver them to customers working in offices and factories. The menus of bento manufacturing companies include daily bento, rice bowls, and noodles.

The attraction of the Japanese daily bento is that one can enjoy a variety of flavors at once. A bento consists of rice as the staple food, a main dish, and a side dish. It contains dishes of different flavors. Another attraction of the Japanese daily bento is the variety of cooking styles. They include Japanese, Western, and Chinese styles.

In menu planning for a daily bento, it is important to combine dishes with a variety of flavors and foods with different textures. If customers feel tired of eating, the number of customers buying bentos will decrease which leads to decrease in sales. In creating a multi-day menu, it is necessary to consider various constraints such as the frequency of serving food, cooking methods, and budget.

However, it is very difficult to manually find a combination of dishes that satisfies these many constraints. In addition, the contents of menus vary depending on person to person in charge of creating menus, and it is difficult to continue preparing high-quality menus for a long period of time.

The purpose of this study is to propose a menu planning model based on mathematical optimization. We consider menu planning as "finding optimal combinations of dishes for multiple periods from a set of dishes that satisfy various constraints in the field, taking into account similar dishes and ingredients". Then, we formulate a menu planning model for catered lunches as a "combinatorial optimization problem" in mathematical optimization. We took account of 37 constraints, including the constraint of similarly flavored dishes.

In order to show effectiveness of the proposed model, we conduct numerical experiments using menu data provided by a company that produces 13,000 meals a day in Kanagawa Prefecture. The worker in charge of planning the menu selects five to six dishes from 738 different dishes to complete the daily menu. The company holds meetings on menu planning twice a month, and manually make the tables of multi-period menus over a long period of time.

As a result of numerical experiments using the mathematical optimization solver Gurobi Optimizer, the menu created by the proposed model was evaluated by experts who have been in charge of menu planning more than 10 years. They regarded the menu created by the proposed model as a menu that can be served on-site. In addition, the time required to prepare the menu was less than 10 minutes. The time required for menu preparation was significantly reduced compared to manual menu preparation.

Keywords Mathematical optimization, Menu planning, Optimal combinations, Dish combination

Biographies

Kazumasa Sugawara is with Department of Industrial Engineering and Management, Graduate School of Engineering, Kanagawa University. His research involves creating menus of bento based on mathematical optimization. He entered Kanagawa University in 2017 and joined the Management Systems and Engineering Laboratory in 2019. After he received his undergraduate degree in Industrial Engineering and Management in 2021, he entered the graduate school of Kanagawa University. In March 2021, he received Excellent Student Award from the Japan Industrial Management Association for his performance at the university. Also, in May 2021, he received the Best Presentation Award from the Japan Industrial Management Association for his work on industry-university collaboration in the research field of Industrial Management.

Kazuki Ota is with Department of Industrial Engineering and Management, Graduate School of Engineering, Kanagawa University. He entered Kanagawa University in 2015 and joined the Management Systems and Engineering Laboratory in 2017. After he received his undergraduate degree in Industrial Engineering and Management in 2019, he entered the graduate school of Kanagawa University. In March 2019, he received the Excellent Paper Presentation Award at the Electrical Society "Electronics, Information and Systems Division Study Group". This award is given to presenters under the age of 35 who presented outstanding papers at the Institute of Electrical Engineers of Japan "Electronics, Information and Systems Division Study Group" last year. Also, he received the "Best Student Paper Award" at the "International Conference on Machine Learning and Data Analysis 2019" held at the University of California, Berkeley in the United States. This award is given to outstanding papers from the viewpoint of uniqueness and importance from among student research presentations. He received his master's degree in Industrial Engineering and Management in 2021.

Hideki Katagiri is a Professor of Department of Industrial Engineering and Management at Kanagawa University, Japan. He earned his B.E., M.E. and Ph.D. in Engineering at Osaka University in 1995, 1997 and 2000, respectively. He was the Chair of IEEE SMC Hiroshima Section Chapter (2008-2010) and a Visiting Scholar at the University of Chicago Booth School of Business (2014-2015). He was a Visiting Professor of Hiroshima University (2016-2020). His research and teaching activities are in the areas of operations research and soft computing, especially, multi-objective optimization under uncertainty and data analysis using machine learning techniques. He is the author or co-author of more than 100 refereed journal papers and several co-authored or co-edited books in English.